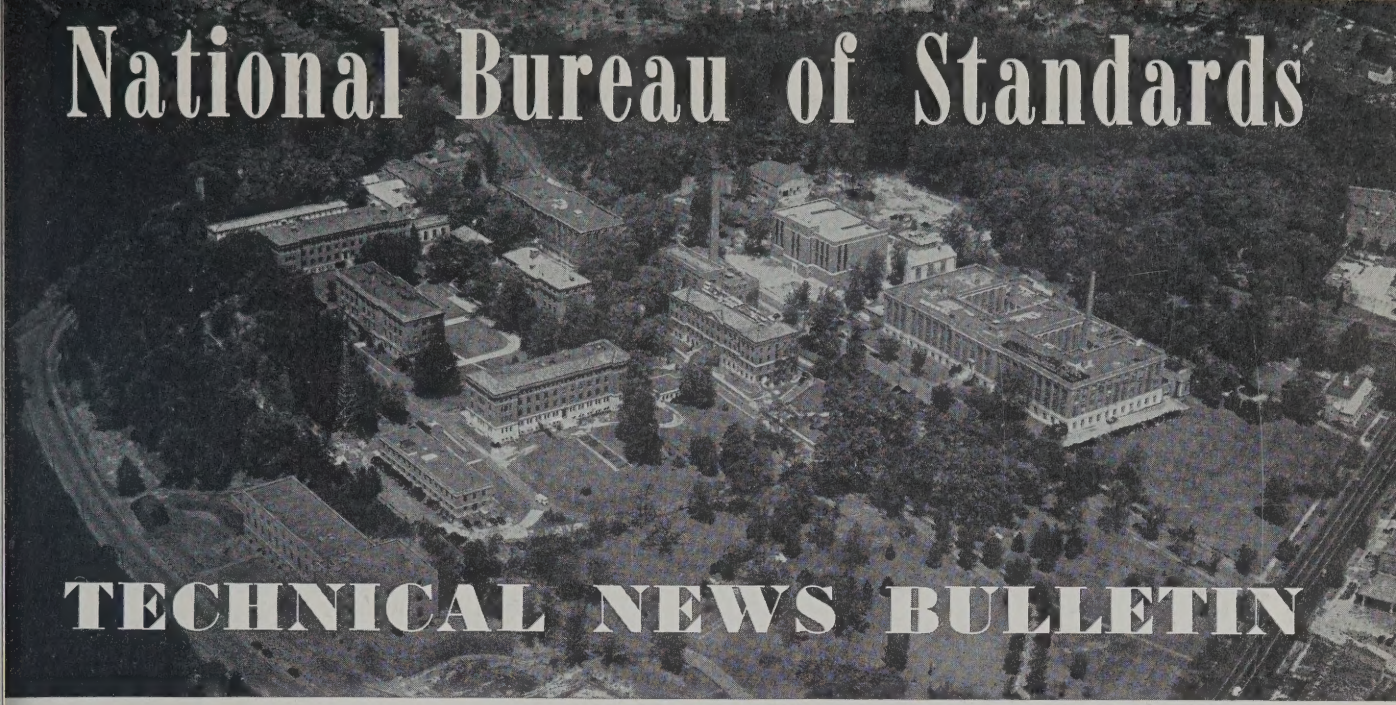
National Bureau of Standards



TECHNICAL NEWS BULLETIN

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NBS Physiological Monitor

Electronic Instrumentation for the Operating Room

AN ELECTRONIC INSTRUMENT which automatically detects changes in the physiological condition of a patient under anesthesia throughout the course of an operation has been developed by the National Bureau of Standards working under sponsorship of the Veterans' Administration. Known as the NBS Physiological Monitor, this instrument measures changes in the patient's blood pressure, heart beat, and respiration as they occur and presents the data on a panel for interpretation by the surgeon or anesthesiologist. A permanent record of the patient's condition during the operation is also provided by a recording device incorporated in the assembly.

Because the Physiological Monitor provides a continuous indication of the patient's physiological condition during surgery, it should prove of great value in the prevention and control of emergencies which may unexpectedly confront the surgeon at the operating table or during certain critical postoperative periods. The instrument is also expected to be a distinct aid in those phases of medical research—such as studies of the effect of drugs on blood pressure—that require a knowledge of the behavior of physiological variables over long periods.

Development of the Physiological Monitor was carried out by S. R. Gilford and H. P. Broida of the NBS staff. Financial support was provided by the Veterans' Administration and by a program of basic instrumentation sponsored at NBS by the Office of Naval Research, the Office of Air Research, and the Atomic Energy Commission. Though the present equipment was designed and constructed primarily to evaluate the feasibility of electronic instrumentation as an aid to operating room procedure, preliminary trials in medical wards at Mount Alto Veterans' Administration Hospital (Washington, D. C.) and in the operating room at George Washington University Hospital have indicated great potential usefulness to the surgical team.

During surgery it is vital that the condition of the patient be known at all times. Ordinarily the anesthesiologist measures blood pressure and pulse rate at sufficiently close intervals to maintain a satisfactory evaluation of the patient's condition. If necessary, he administers drugs, additional anesthetics, or infusions of blood or plasma. However, when the anesthesiologist is occupied with his other duties, longer periods may elapse between measurements. Although in most cases this delay is not serious, at other times it can result in unfortunate consequences. For example, when complete circulatory collapse occurs—as in severe blood loss or in heart failure—there may be some lapse of time before the condition becomes outwardly apparent. Since time is important in applying remedial measures, the earliest possible detection of such a crisis offers the best hope in saving the life of the patient.

The NBS Physiological Monitor makes prompt emergency action possible by continuously displaying the information the anesthesiologist needs to know in sim-

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Laboratory evaluation of the NBS Physiological Monitor using a human subject. The operating room console (right foreground) indicates changes in blood pressure, heart beat, and respiration as they occur. A permanent record of these readings is automatically made on the chart of the recorder console (left background). Electrical attachments to the subject's arms and legs permit continuous measurement of pulse rate and pulse irregularity. The arm band and associated microphone are for measurement of blood pressure. In actual use, the recorder console is placed outside of the operating room.

ple, numerical form. Data on systolic and diastolic blood pressure,[1] pulse rate and pulse irregularity, breathing rate, and amount of air breathed out per minute are available at a glance without intermediate calculation or manipulation. Preliminary adjustments are easily made, requiring no special technical skill or training on the part of the operator. Safeguards are provided to permit the instrument's use in the highly combustible mixtures of anesthetic gases that are usually present in the operating room. Size and weight of the equipment have been minimized for easy moving, and the amount of floor space required has been kept as small as possible.

While individual systems were already in existence for performing some of the functions of the Physiological Monitor, for other functions it was necessary to develop entirely new methods of approach. In general, the problem was to integrate the various component measuring and indicating systems into a complete instrument which would function smoothly and safely in the operating room and which would present results in a clear, easily interpreted manner.

All of the electronic assemblies used in the Physiological Monitor were made so as to be easily replaceable, and the "plug-in" type of structure was chosen to facilitate servicing. Sufficient flexibility was built into the present experimental model to permit the inclusion of instrumentation for measuring additional physiological quantities as further developmental work is done on the instrument.

[1] Systolic pressure is associated with the heart's contraction, diastolic pressure with heart expansion.

General Description

The Physiological Monitor is housed in two metal cabinets—the *operating room console* and the *recorder console*—interconnected by a combination electrical cable and air line permitting a maximum separation of about 20 feet.

The operating room console, which has been rendered safe for use in the presence of explosive vapors, is 3 feet high and occupies 22 by 26 inches of floor space. It provides a compact, easily read display of the results of all measurements as they are made. This unit also contains the controls used to place the instrument in operation. All attachments to the patient are made from this unit, which houses most of the measuring equipment.

The recorder console, 5 feet high and occupying 22 by 24 inches of floor space, is designed to be placed outside of the operating room, where explosive vapors are not present. This unit contains a recorder which provides a permanent record of the measurements indicated on the operating room console, additional circuit components, and an air supply for use in blood pressure measurement and for pressurizing the operating room console to keep it free of explosive vapors.

Blood Pressure Measurement

The automatic system used in the Physiological Monitor for measuring blood pressure is based upon the technique commonly used by an examining physician. The physician forces air into a hollow

band, or cuff, surrounding the arm until the systolic pressure is exceeded; he then gradually reduces the pressure and determines systolic and diastolic pressures by noting the pressure reading on a manometer when certain characteristic pulse sounds in the artery are detected with a stethoscope.

In the automatic system, a microphone is located at the point of observation over the brachial artery. Every 3 minutes the valve of an air supply automatically opens, allowing the pressure within the arm band to increase. As soon as the pressure in the band exceeds the diastolic value, the microphone begins to pick up sound within the artery. This sound reaches a maximum and decreases, disappearing after the pressure in the band exceeds the systolic point. By means of a system of amplifiers and relays, the pulses picked up in the microphone actuate two solenoid valves in the air system which open to connect the system to the proper pressure indicating gages at the diastolic and systolic points. The valves close almost immediately after opening so that the diastolic and systolic pressures—now converted by a transducer to electrical signals—remain registered on the indicating meters until the next measurement cycle begins.

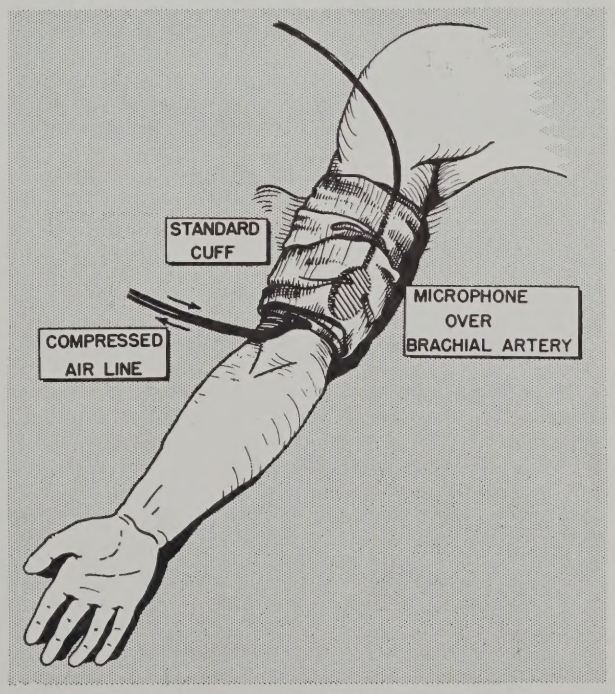
The amplifier and relay circuit are arranged in such a way that when the microphone receives the initial sound from the artery, the first valve opens, permitting the adjacent gage to register the diastolic pressure. Since it is not possible to determine the point at which sound disappears until that point has been passed, the pressure is now carried beyond the systolic point and then allowed to decrease slowly until the systolic pressure is again reached. As the first sounds corresponding to the systolic pressure are received, the second valve opens, allowing its adjacent gage to "capture" and retain the instantaneous pressure of the system. The band is then rapidly deflated to minimize the period during which pressure is applied to the patient's arm.

The entire process proceeds under the control of a program switch which initiates the measurement at 3-minute intervals. The actual determination takes about 1 minute or less for the normal range of pressure but is dependent upon the maximum pressure the system must reach. The relay system selects the proper pressure registration valve corresponding to the systolic or diastolic measurement and permits only the first sound pulse to operate the registration valve. The relay system also starts the deflation of the arm band after the systolic pressure has been exceeded by a safe margin (as indicated by the cessation of sound) and finally opens a second valve which rapidly deflates the band after the systolic pressure has been recorded.

The microphone-amplifier combination selects sound pulses of the required amplitude and frequency content, and converts them into electrical pulses of uniform amplitude and duration which actuate the relay and control circuits. Because the sound originating in the artery is considerably attenuated by the time it emerges from the tissues, the microphone-amplifier circuit must be quite sensitive to low-amplitude pulses. At the same time it must minimize unwanted signals originating from microphone frictional noises and random sounds in the immediate vicinity. By improvement of the microphone, by shaping of the amplifier pass band characteristics to the restricted band of signals, and by development of special coincidence and verification circuits, it was possible to construct a sensing device which sharply outlines the end points and is virtually undisturbed by spurious signals.

A crystal microphone with good response at the lower audio frequencies was incorporated into a standard stethoscope chest piece. The microphone is thoroughly shielded to keep electrical noise out of the amplifier input. The output of the microphone is applied to a three-stage conventional RC-coupled amplifier having a gain of approximately 80 decibels. This is followed by a low-pass filter which starts to cut off above 100 c/s.

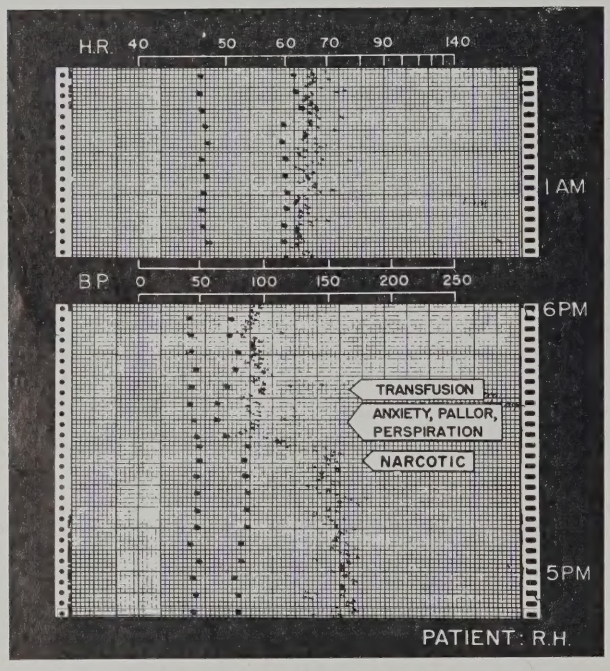
The output of the filter is introduced into a pulse stretching and equalizing circuit in the form of a monostable multivibrator. A neon tube connected to the plate of the normally nonconducting triode of the multivibrator flashes each time a pulse triggers the multivibrator. This neon tube, located on the instrument panel, serves as an indicator which permits the operator to adjust the gain in the system to the characteristic sound level of the subject.



Artist's drawing of a patient's arm showing the attachments for measurement of blood pressure. Hollow cuff surrounding arm is inflated automatically at intervals by an external air source. A microphone is located over the brachial artery to detect sound pulses. These pulses are amplified by an electronic circuit and made to actuate a valve-and-gage device which indicates and records the pressure in the system at the time it is equal to the patient's blood pressure.

The system for discrimination between the sound pulses produced within the artery and other noise signals is based upon the fact that the sounds within the artery are accompanied by corresponding slight increases in pressure within the arm band. The coincidence circuits reject all sound pulses that do not coincide with the necessary pressure pulses. As a further protection, these circuits prevent actuation of the relay system by any sound pulse that is not followed by a similar pulse within one-half second.

The blood pressure measurement system has been used on many different human subjects for periods ranging from an hour to as long as 21 hours under hospital conditions. In general, it appears to cause the patients no discomfort and permits them to eat, sleep, and carry on other activities of a bed patient.



Clinical record of a hospital patient as recorded by the NBS Physiological Monitor. The two traces of larger dots show the rise and fall of systolic and diastolic blood pressure (B. P.); the smaller dots represent heart rate, or pulse rate (H. R.). Injection of the patient with a narcotic about 5:30 p. m. produced an unusual response characterized by anxiety, pallor, perspiration, and a drop in both blood pressure and pulse rate. A blood transfusion was given shortly before 6 p. m., resulting in a gradual rise in blood pressure and pulse rate.

Good agreement has been found between instrument values of blood pressure and those obtained in the usual way. Changes in pressure following the administration of drugs affecting blood pressure are easily followed.

Measurement of Pulse Rate

It is important to monitor the pulse rate during anesthesia, since the action of some of the anesthetic drugs and the effect of surgery tend to increase cardiac irritability. The system used in the Physiological Monitor to measure pulse rate is a modification of a method described by Sturm and Wood.[2] While the physician ordinarily checks heart beat, or pulse rate, by counting the pulsations of an external artery, this method obtains the information by measuring the periodic changes in the very small voltage produced by the heart. Electrical connections are made to the patient's arms and legs as in the use of the electrocardiograph for study of heart conditions.

By means of suitable circuitry, the time between adjacent pulses in the cardiac potential is continuously measured and converted to rate on a specially calibrated meter. Thus the instantaneous heart rate is measured, rather than the average rate over a given period. This makes it possible to follow irregularities and abrupt changes in heart beat.

The time intervals between heart beats are made proportional to the voltage across a linearly charged capacitor. Each cardiac pulse discharges the condenser to zero, after which the voltage begins its linear increase. The peak voltage reached at the time of each pulse is stored in a capacitor memory to which the first capacitor transfers its charge.

The input from the patient electrodes is applied to a differential amplifier input stage, which is adjusted to give good discrimination against electrostatically induced interference from the power line. The resulting output is amplified by several additional stages and is applied finally to a pulse shaper in the form of a monostable multivibrator. The signal level is adjusted to trigger the multivibrator once each cardiac cycle. This causes the momentary actuation of a relay which transfers the voltage across the timing capacitor to the storage capacitor and then resets the timing capacitor to zero voltage. An indicator lamp flashes in synchronism with the pulse, providing a convenient means for obtaining the patient's pulse rate by the conventional method if desired.

Once the electrodes are adjusted, the operator has only to read the values of pulse rate from the dial. Continuous measurements have been made on medical ward patients for as long as 21 hours without difficulty.

Measurement of Cardiac Irregularity

Arrhythmia, or cardiac irregularity, may be the forerunner of serious difficulties for the patient in the operating room. However, objective measurement of arrhythmia is complicated by the fact that both changes in rate and occasional irregular beats occur under normal as well as abnorml conditions. The system developed by the Bureau was therefore designed to weigh the rate of occurrence of such "arrhythmic incidents" rather than to indicate these events individually.

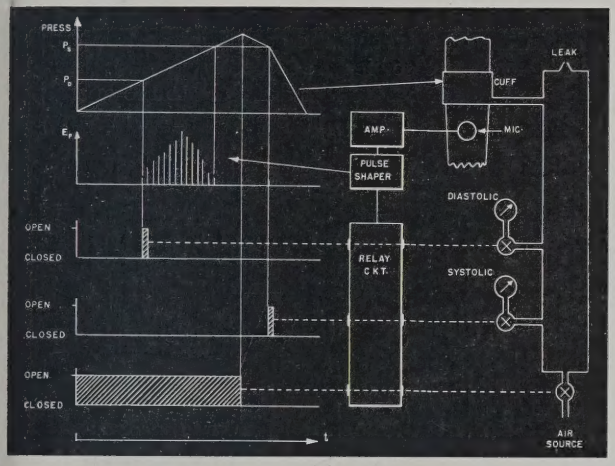
The system operates by comparing the time intervals between adjacent pairs of beats on a continuous basis.

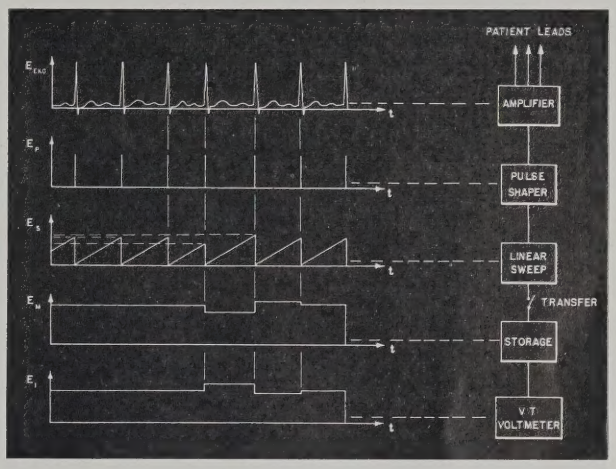
[2] *An instantaneous recording cardiotachometer*, by R. E. Sturm and E. H. Wood, *Rev. Sci. Inst.*, [*10*] **18** (*1947*).

Time differences of 25 percent are arbitrarily defined as arrhythmic incidents. The circuit gives the average time rate of these occurrences and presents it on an arbitrary scale.

This measurement is accomplished rather simply through use of the circuit developed for measuring pulse rate. If the heart beats are uniformly spaced, then only enough charge will be transferred to the memory capacitor to replace its losses, which are relatively small. However, should there be a considerable discrepancy between beats, then the memory capacitor has to receive or give up enough charge to bring it to the required level. In this process current flows, and if the magnitude of this current exceeds a certain value, it is used to indicate an arrhythmic incident.

Each time a pulse of current flows to the storage capacitor it passes through the primary winding of a transformer. The voltage pulses from the secondary are introduced into a pulse height discriminator. Whenever a pulse is of sufficiently high amplitude, the discriminator produces an output pulse that is fed into an integrator circuit. The time average of these pulses appears on the output indicator. For purposes of studying the system's response to arrhythmia, a circuit is also included which automatically turns on an electrocardiograph whenever unusual irregularity of heart beat is indicated.





Left: **Block diagram of system used for measuring blood pressure. Small graph at upper left shows the rise and fall of pressure within the arm band, or cuff. Systolic and diastolic points are indicated as P_S and P_D. The gradual increase and decrease of sound pulses in the microphone are plotted below on the axis marked E_P. Three small graphs at lower left show the opening and closing times of the three valves in relation to pressure**
Right: **Block diagram of the system used for measurement of pulse rate. Accompanying graph at upper left shows the actual time variation of the small voltage produced by the heart beat. Successive graphs below show the changes in the form of this signal as it is acted upon by the successive units of the system.**

Measurement of Respiratory Rate and Volume per Minute

While measurements of respiratory function are not ordinarily available during an operation, such information should be of considerable value. Under general anesthesia those parts of the brain which normally control respiration become depressed to an extent depending on the depth of anesthesia. Also, some surgical procedures involving the thoracic cavity are accompanied by mechanical impediments to breathing. Development of a system for obtaining information on respiration rate and volume should permit the routine application of these measurements during surgery and should also provide a means for determining their value to the anesthesiologist.

The basis of the respiration measuring equipment in the Physiological Monitor is a positive displacement flowmeter in which the rotation of the output shaft is proportional to the volume of gas that has passed through the meter. For measurement of volume of flow per minute, the shaft of the flowmeter is periodically coupled to an indicating system for 1 minute. The accumulated volume indicated for this time is preserved until the next determination by a memory system consisting of a synchronous motor-generator pair.

During each 1-minute registration period, the shaft of the flowmeter is coupled through a clutch to the synchro-generator, and the synchro-generator is electrically disconnected from the synchro-motor. At the end of the 1-minute measuring interval, the generator is declutched from the flowmeter shaft, its shaft clamped, and electrical connections completed to the synchro-motor. The motor shaft immediately assumes an angular position corresponding to that of the generator shaft. The electrical connection between generator and motor is then broken, so that the motor shaft retains the angular information transferred from the synchro-generator. The motor shaft carries with it the movable arm of a potentiometer which translates angular position into a voltage suitable for meter indication and recording. At the end of the cycle, the generator shaft is brought back to its original starting point and again coupled to the flowmeter.

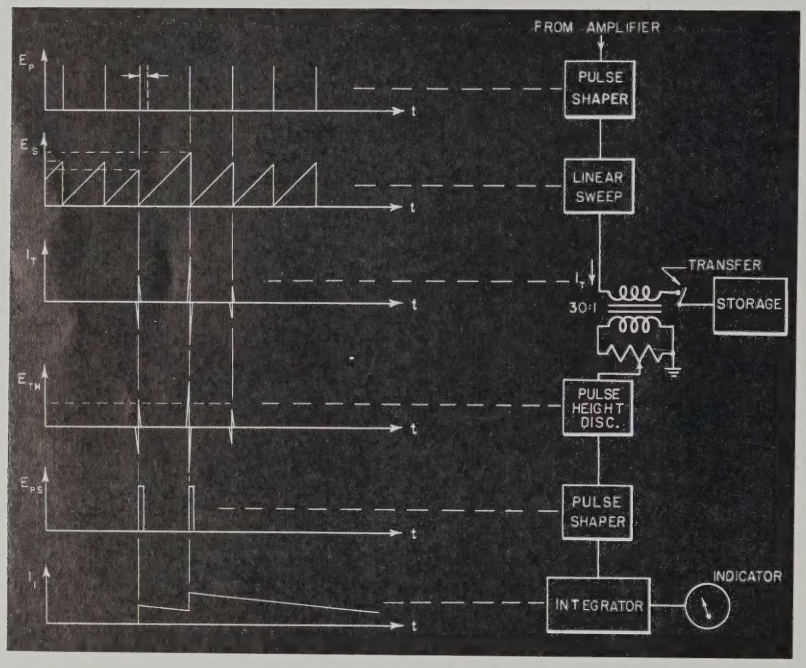
Respiration rate is determined as the number of

times the shaft of the flowmeter starts and stops within a given time as the patient breathes in and out. The motion of the shaft is followed by means of an attached multitoothed wheel. As the shaft rotates, this wheel alternately opens and closes a pair of electrical contacts. Each actuation of the contacts discharges a capacitor which controls the potential of a trigger circuit. As long as the contacts continue to open and close, the control potential is held to a value below the triggering threshold. But as soon as contact actuation is interrupted for a time indicating momentary cessation of motion, the trigger operates and sends a pulse into a register. Each pulse thus indicates one respiration.

The pulse count is accumulated on a 50-point telephone-type stepping switch, where it is converted into the angular displacement of the switch shaft. This shaft is coupled to a synchro-generator which transfers its angular position to an indicating synchro-motor during the indication period in a manner similar to that of the minute volume recorder. The stepping switch is then reset to its zero position.

To prevent the accumulation of electrostatic charges, the operating room console is equipped with conductive rubber casters grounded to the metal frame. However, the use of explosion-proof fixtures, as in fixed electrical installations for power line equipment, did not appear feasible for portable equipment of this size. Instead a system based on the maintenance of a small positive pressure within the enclosure was designed. This made it unnecessary to seal the enclosure hermetically, although reasonable care was taken to keep the leakage small by restricting the size of openings. Thus, for example, the instrument panel is covered with a sheet of safety glass and sealed to the instrument case by means of a rubber gasket and compression frame.

A sliding vane compressor in the recorder console maintains the interior of the operating room console at about one-half pound pressure above that of the outside. Noise is eliminated by an acoustic filter located in the inlet side of the compressor. The output air of the compressor is first cooled by passage through a heat exchanger before it is delivered to the operating room console. Safeguards are provided which prevent



Block diagram of the circuit used for measurement of arrhythmia, or irregularity of heart beat.

Safety Features

Common use of explosive gas mixtures for anesthesia makes it necessary that potential ignition sources be supplied with safeguards to prevent occurrence or propagation of explosions. The electrical equipment required in the operating room console contains voltage sources, contactors, motors, and numerous hot filaments, all of which could serve as sources of ignition under certain conditions. Equally important as ignition sources are possible static charge accumulations on surfaces of the equipment and accidental connection of the instrument housing or any of its parts to the power line through insulation failure.

the application of any power to the unit in the operating room unless the purging pressure is present. Also, a time delay inserted in the power line insures that the purging system must be in operation for about 2 minutes before power can be applied to the unit.

To insure the safety of the patient against possible short circuits or other accidental sources of electrical hazard, the electrodes used in measuring heart beat are designed so that high-ohm resistors can be placed in each of them. Safety provisions have also been incorporated in the blood-pressure measurement device to guard against the application of excessive pressure to the arm of the patient or, what is worse, the main-

tenance of an occluding pressure for long periods. Excessive pressures are prevented by a mechanical pop-off valve which opens and relieves arm-band pressure when the system pressure exceeds a preset value. In addition, an adjustable electrical limit switch is set to cause deflation of the arm band whenever the system pressure exceeds a value reasonably well above the patient's systolic pressure. In the event of power failure, air is discharged from the system by a solenoid-operated exhaust valve which normally functions to discharge the system at the end of each blood-pressure determination.

National Conference on Weights and Measures

AN INNOVATION marked the thirty-ninth meeting of the National Conference on Weights and Measures held in Washington, D. C., on May 17 to 21, 1954. The meeting was extended to 5 days, the additional day being devoted to open hearings by the five standing committees and one special committee of the Conference, preliminary to the formal program sessions that were held on the 4 succeeding days. These hearings were well attended, and served to resolve numerous debatable issues and to develop agreements later embodied in the reports of the several committees to the Conference.

Official registration established a new record of 455, of which 211 were weights and measures officials from 39 States and the District of Columbia, 110 were representatives of manufacturers of weighing and measuring devices, and 78 were representatives of trade associations, business, industry, railroads, and similar organizations. Guests were present from three foreign countries, Belgium, Brazil, and England.

The Conference was opened with addresses by Hon. Walter Williams, Under Secretary of Commerce, and Dr. A. V. Astin, Director of the National Bureau of Standards and President of the Conference. During the meeting, papers were presented on numerous weights and measures topics, including a cooperative Federal-State program for the testing of livestock scales, prepackaged foods, a forecast of developments in the scale industry, the evolution of gasoline pumps, an electronic flowmeter, the testing of farm milk tanks, LPG meter testing, fabric-measuring devices, the determination of vehicle axle loads, and weights and measures approval seals.

At the invitation of the Director, the Conference nominated six persons for membership on a Weights and Measures Advisory Committee to the National Bureau of Standards. The nominees and their respective terms were: W. M. Harks, Bowser, Inc. (1 year); A. V. Hokanson, National Association of Retail Grocers (1 year); C. M. Fuller, County Sealer of Weights and Measures, Los Angeles County, Calif. (2 years); B. H. Dreese, Hobart Mfg. Co. (2 years); J. P. McBride, Director of Standards of Massachusetts (3 years); H. J. Kennedy, Continental Oil Co. (3 years).

The standing committee on Specifications and Tolerances recommended minor changes in the codes for linear measures, liquid-measuring devices, vehicle tanks, and scales; more extensive changes in the code for taximeters; and revision and final adoption of the previously *tentative* code for farm milk tanks. These recommendations were adopted by the Conference.

The standing committee on Weights and Measures Education reported upon the planning of educational displays, and by means of slides illustrated many such displays that had been used successfully in various jurisdictions. Also, the Committee's earlier recommendations relative to salary schedules for weights and measures officials were revised. The report of the standing committee on Methods of Sale of Commodities included fourteen specific recommendations. Reports were made by the two remaining standing committees, on Legislation and on Trading by Weight, and by the special committee on Packaged Flour. All committee reports were adopted.

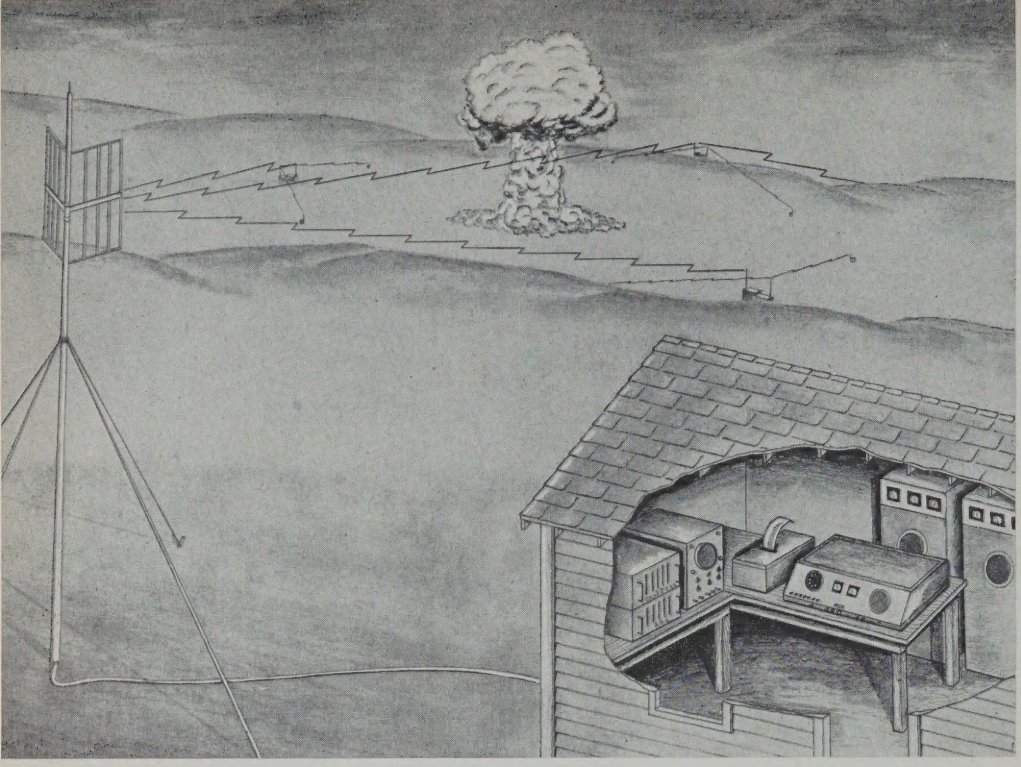
One half-day session of the Conference was devoted to a demonstration of farm-milk-tank testing, a discussion and demonstration of LPG-meter testing, the viewing of a weights and measures motion picture produced by a local officer in Massachusetts, and by visits to NBS laboratories.

Dr. Astin was reelected President of the Conference. Six vice presidents were elected: J. Roy Jones (South Carolina), J. W. Reese (Iowa), C. A. Lyon (New Hampshire), G. L. Johnson (Kentucky), A. O. Oslund (Union City, N. J.), and W. L. Daniels (Seattle, Wash.). W. S. Bussey (NBS Office of Weights and Measures) was reelected Secretary, and G. F. Austin, Jr. (Detroit, Mich.) was elected Treasurer.

The 40th National Conference will be held in Washington, D. C., on May 16 to 20, 1955.

Thirty-Eighth Conference

Report of the Thirty-Eighth National Conference on Weights and Measures, 1953, is now available. It covers such topics as prepackaged foods, flour weights, automatic packaging machinery, livestock weighing supervision, electronic scales, technicalities in weights and measures court cases, the proposed international conference on legal metrology, and the performance of inspectors and gasoline pumps. The report also includes actions of the conference with regard to recommended methods of sale of a variety of products. Miscellaneous Publication 209, 116 pages, 40 cents. Order from Government Printing Office, Washington 25, D. C.



Radiat

Atom

THE BUREAU has developed a remote-control system which automatically measures radiation intensities and other variables in the vicinity of an atomic explosion and transmits the data by radio to a centrally located headquarters. The system was designed at the request of the Division of Biology and Medicine of the Atomic Energy Commission for use in nuclear tests. Though developed specifically for monitoring gamma radiation and weather conditions, it can be used with a wide variety of detectors to report many types of information. Except for the control station, the entire system is battery powered and will operate unattended for long periods.

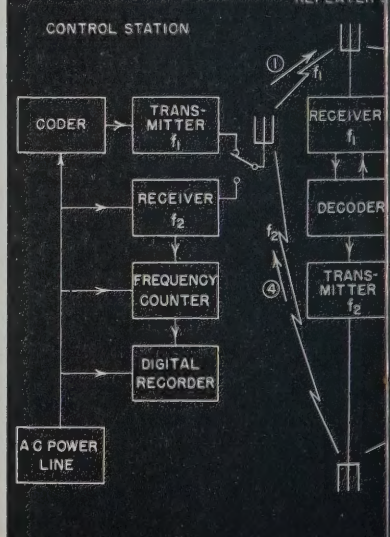
The overall design of the NBS radiation monitoring system was worked out by L. Costrell, G. Minton, and E. R. Saunders of the Bureau's nucleonic instrumentation laboratory. It permits the operator at the control station to select one of several data stations for transmission of data and to determine what particular type of information is to be reported. The radio link and the station interrogation system were designed and constructed by the Motorola Corporation and are based largely on their ¼-watt portable transmitter-receiver and other standard equipment.

The radio link is a frequency-modulated system operating in the VHF band between 162 and 174 megacycles. Since line-of-sight transmission is required at these frequencies, the link employs repeater stations located at positions of high elevation. Each repeater can handle information from 10 data stations, and each data station offers a choice of 10 different programs—each having several functions—which the operator can select for transmission to the control station. Thus, for example, one program might consist of station identification, several calibrations, and radiation intensity readings while another program might contain weather information.

Battery power is conserved by means of cycle timers at the repeater and data stations. The cycle timers operate in conjunction with a coder unit in the control station, which enables the control station operator to select the desired repeater and data stations. The cycle timers regularly turn the receivers at these stations on

Above: **Schematic drawing of the remote-control system for monitoring radiation produced by an atomic explosion. Repeater stations at elevated positions permit radio communication at VHF frequencies between the central control station (lower right) and the various data stations distributed about the center of the explosion.**

Block diagram of the radiatio station transmits on an r-f fre at the repeater and retransmitt f_2. The data station transmi signal is picked up by the rep the control station on frequen



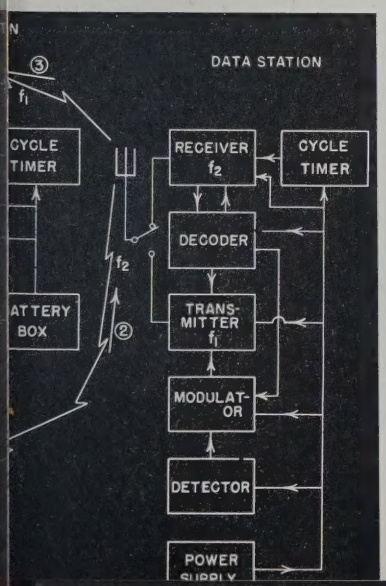
on Monitor for

c Explosions

for 2 seconds out of every 20. If during the "on" part of the cycle the coder unit sends out a properly modulated signal indicating that the control station desires to communicate with a particular repeater or data station, the receiver at this station will be locked on and will no longer be controlled by the cycle timer. As cycle timers are installed at both repeater and data stations, the control station must transmit its coded signal for approximately 40 seconds in order to be sure to "capture" the repeater station and to have the repeater capture the data station.

After the repeater and a data station have been captured, the control station operator can then direct the data station to transmit the desired program of information. He does this by dialing the proper program number on the control console, which serves to energize the transmitter and modulator at the data station. The data station then transmits the desired program through the repeater to the control station. The information is transmitted in the form of a variable frequency covering the range of approximately 750 c/s to approximately 4 kc. At the control station this audio frequency is fed to a frequency counter, where it is counted and displayed in alternate 1-second periods and also printed on a digital recorder. Calibration curves of radiation intensity or other quantities as a function of frequency are utilized in interpreting the frequency variations in terms of the measured data.

nitoring system. The control ncy f_1. This signal is received the data station on frequency ack on frequency f_1, and the r station and retransmitted, to



After the program has been completed, the data station receiver remains active for a short period, ready to accept further program challenges. The equipment is then automatically de-energized, and the cycle timer again assumes control, activating the receiver 2 seconds out of every 20.

Data Station

Each data station includes a transmitter-receiver, cycle timer, decoder, program selector, modulator, battery power supply, and detecting instruments. The decoder is a mechanically resonant device that activates the program selector when actuated by the proper incoming frequency. The program selector then receives impulses consisting of interruptions to the modulated subcarrier signal which are produced by the dialing mechanism in the control station coder console. These impulses occur at a rate of about 10 per second. The program selector utilizes a stepping relay and associated circuity to advance one step for each impulse it receives. Thus, if the operator dials program No. 6, for example, six interruptions occur, causing the program selector stepper in the data station to advance to position No. 6.

After the program selector stepping relay has been advanced by the decoder to select the desired detector (radiation intensity, wind velocity, etc.), the output of

Above: **On-the-spot check of one of the data stations of the NBS system for monitoring radiation from an atomic explosion.**

this detector is routed to a function selector stepping relay. The function selector is advanced one position every 15 seconds by the cycle timer. Thus, the various functions—such as station identification, calibrations, and data from the detectors—are routed to the modulator in sequence to be transmitted to the repeater station. In the final step the modulator and transmitter are turned off though the receiver remains active for another 2 minutes to permit it to respond rapidly to further interrogation.

The modulator used is essentially an oscillator with a variable inductance for controlling the frequency of oscillation. Negative feedback is used to give amplitude stability and to limit the variation of amplitude with frequency.

Radiation detectors were designed at the Bureau for this application having a range of 0.02 milliroentgen per hour to 10 roentgen per hour. They were calibrated in the field using gamma radiation from cobalt-60 and a specially designed calibrating jig.

Repeater Station

The repeater station consists essentially of a transmitter and receiver, with duplicate stand-by equipment. It also includes a cycle timer, decoder, and battery box. The repeater station is so designed that the control station operator can select either of the two receivers and either of the two transmitters in the instrument. This duplication of equipment is included since complete failure of the repeater would prevent reception from any of the data stations operating through it.

Control Station

The control station contains duplicate transmitting and receiving equipments. Standard 30-watt transmitters are used. The two receivers are sharply tuned for high selectivity. In addition, where required, a cavity resonator can be inserted between the antennas and the receiver to give even higher selectivity.

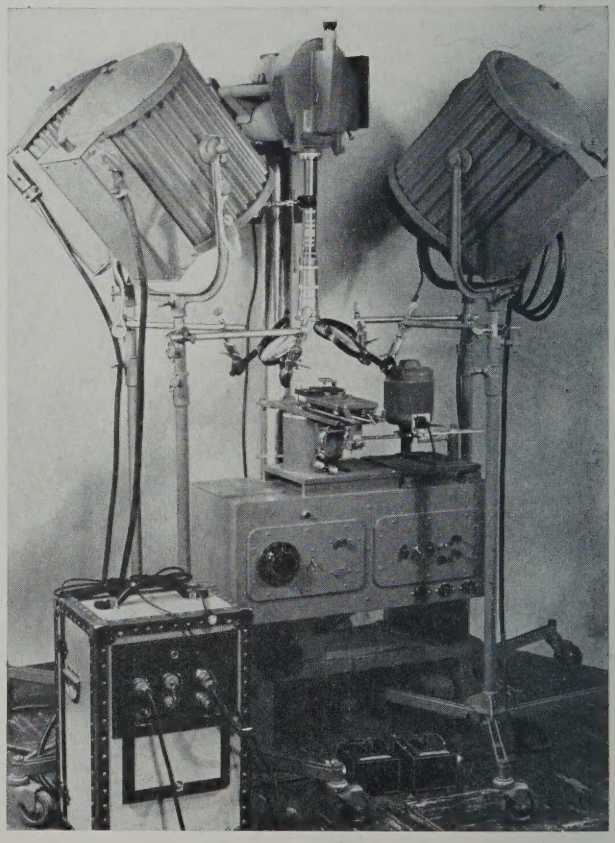
The remote control console contains 12 push buttons and a dial similar to that used on telephone systems. Ten of the push buttons are for data station selection; the remaining two are used to select the desired receiver and transmitter at the repeater station. The dial is for choice of data programs.

The demodulated signal from the receiver is first amplified and then fed to a gated counter which counts the input cycles for a period of 1 second, displays the result for about a second, and then repeats the cycle. A digital printer records the output frequency as it appears on the frequency counter.

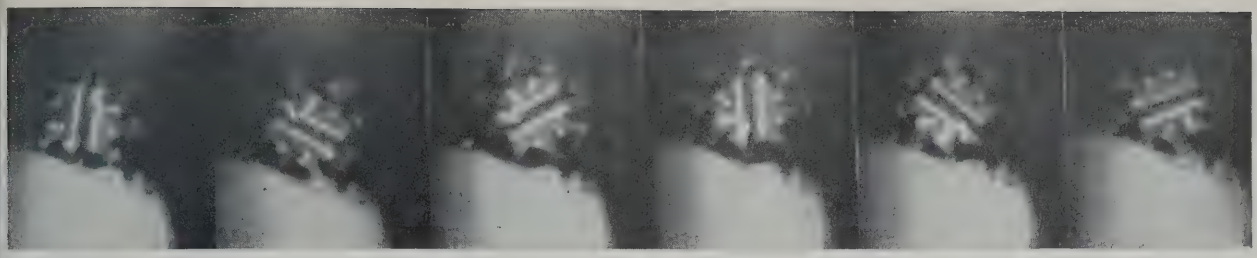
Study of Dental Burs

SIGNIFICANT information on the cutting action of rotating dental instruments has been provided by a photographic technique recently developed at NBS. In this technique, a high-speed motion picture camera is used in combination with an optical magnification system to make a greatly enlarged, slow-motion record of the action of each blade of a dental bur throughout the cutting cycle. It has thus been possible to obtain dynamic observations of clogging, intermittent cutting, eccentric rotation, and other hitherto unsuspected details of the passage of the bur blades through the tooth structure. Used in combination with conventional test procedures, the photographic method should prove of considerable value for experimental study of new types of dental burs since it will permit rapid evaluation of new designs prior to extended laboratory investigation.

The photographic method was devised and applied by Major Jack L. Hartley and Colonel Donald C. Hudson (both NBS guest workers from the U. S. Air Force Dental Service), and W. T. Sweeney and W. P. Richardson of the NBS staff. The project was part of a program of dental research which the Bureau is conducting in cooperation with the American Dental Asso-



High-speed motion picture camera and auxiliary equipment used for slow-motion photography of rotating dental burs. Four 1,000-watt spotlights, their output concentrated by condensing lenses, are required for the extremely short exposure time. The extension tube directly below the camera contains lenses for magnification. Below the tube is the bur test machine. The camera control unit is at lower left.



Eight-bladed tungsten carbide bur cutting human enamel. Bur was 0.003 inch eccentric. Only 4 of the 8 blades actually cut. Some of the finely powdered debris follows the vortex of air about the bur and is carried back into the excavation. However, bulk of cut material accumulates at exit side.

ciation and the dental services of the Air Force, the Army, the Navy, and the Veterans' Administration.

Until now little has been known regarding the cutting action of dental burs in the cavity preparation of human teeth. Although considerable information is available on the cutting mechanism of industrial abrasive wheels and milling cutters, this information is not directly applicable to dental instruments because the properties of human tooth enamel and dentin differ so greatly from those of other materials and because dental instruments are so much smaller than the industrial cutters. Also, the patient's sensitivity to pain, frictional heat, and vibration is an important additional factor which must be taken into account in the design of dental burs. The high-speed photomicrography program was undertaken to provide basic information that might lead to improvement in the design and use of rotating dental cutting instruments.

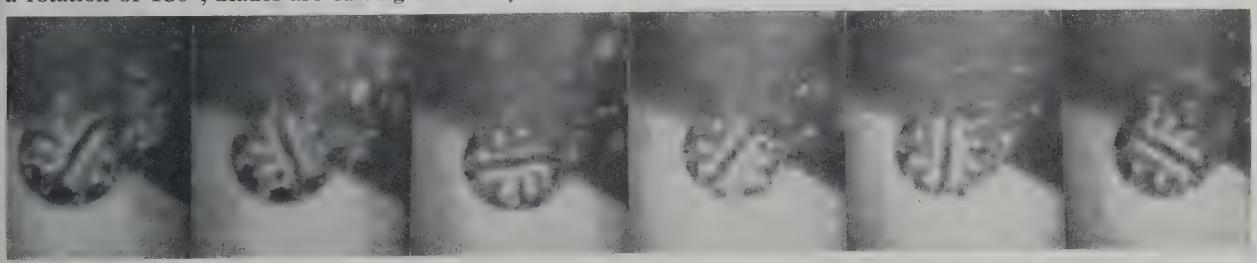
In preliminary investigations a conventional laboratory camera was used with a 2-microsecond light source to produce still photomicrographs of dental burs cutting glass and resin specimens in a standard bur testing machine. While these still photographs were of some value, they did not permit sequential studies of the cutting action of any particular blade under dynamic conditions. It was therefore decided to make continuous observations using motion picture techniques.

Three 16-mm high-speed motion picture cameras were used to study the cutting action of a large number of types of dental burs on mounted specimens of human dentin and enamel. The three cameras operated at speeds of 3,000, 7,000, and 14,000 frames per second; they thus effectively slowed the action of burs rotating at 2,500, 5,000, and 10,000 rpm, respectively, so that all phases of the rotation cycle could be readily studied. These speeds of rotation correspond approximately to low, average, and high dental operating speeds. One hundred-foot rolls of black-and-white reversal film traveled through the cameras in from 0.8 to 1.25 seconds. About one-third of this period was utilized by the camera in building up to top speed. The action recorded on the film was extended for study to approximately 3 minutes by projection at 24 frames per second.

Adequate magnification was obtained by attaching to the camera an 8-inch extension tube containing an

Steel bur cutting human dentin. There is definite chip formation, but chips are fragmented and tend to follow the instrument as it rotates. Study of the debris reveals intermittent cutting.

Tungsten-carbide bur cutting human dentin. Larger chips formed by bur tend to be thrown out of operating field. In first photograph great amount of dentin has been removed by the bur and is leaving the excavation. Blades in cutting position at this stage are ineffective since the instrument is 0.002 inch eccentric. In fourth photograph after a rotation of 180°, blades are cutting effectively.

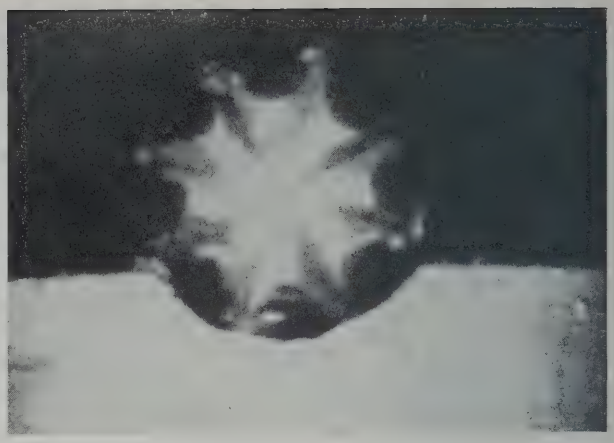


f–4.0, 6-inch telephoto lens and a 2-diopter supplementary lens. The extension tube reduced the indicated *f*-stop of the lens to an effective aperture of *f*–9.2. A high-intensity light source of eleven 750-watt prefocused floodlamps was required for the 3,000-fps camera because of this small aperture and an exposure time of 1/15,000 second per frame. Additional illumination was needed for the faster cameras, since the exposure was only 1/35,000 second for the 7,000-fps camera and 1/70,000 second for the 14,000-fps camera. This illumination was provided by four 1,000-watt spot lights with parabolic reflectors. Their light was further concentrated by means of 2-diopter condensing lenses 4 inches in diameter. Thus, over 300,000 foot candles of light was focused on an area of 2 square inches. The short interval of time involved in turning on the lights, energizing the camera, and turning off the lights prevented any damage to the specimen or equipment from heat.

Much can be learned regarding the operation of the bur blades through observation of the slow-motion films projected on a screen. For more detailed study of individual frames, enlargements are made either from the 16-mm film on direct-positive paper or from negative film, which is used in the cameras when print studies are desired.

The photographic evidence shows that, with very few exceptions, all burs studied were intermittent cutters because of eccentricity and irregularities in blade formation. Chip formation is revealed in detail as the individual bur blades pass through the excavation in the tooth material. A chip that is formed by one type of blade may break away from the parent substance and strike the blade ahead, thus causing clogging. Fine, pulverized chips, produced by a bur which is cutting ineffectively or which is rotating at too low a speed, are seen to follow the vortex of air created by the revolving bur until they are carried back into the excavation. However, the slow-motion studies show a definite improvement in clearance of debris when the speed of rotation is increased from 5,000 to 10,000 rpm.

Eccentricity, evident in all but a few of the burs, causes a definite bounce as the bur cuts tooth structure. As a result, only 3 or 4 blades of an 8-bladed bur actually cut; the remaining blades are not in contact with the specimen when they pass through the excavation. Ineffective cutting is observed when a steel bur is used on human enamel; the bur rapidly dulls and then chatters uselessly. A carbide bur is seen to cut more enamel effectively. The effect of improper design is readily observed in some carbide burs which perform very poorly even though they do not dull.



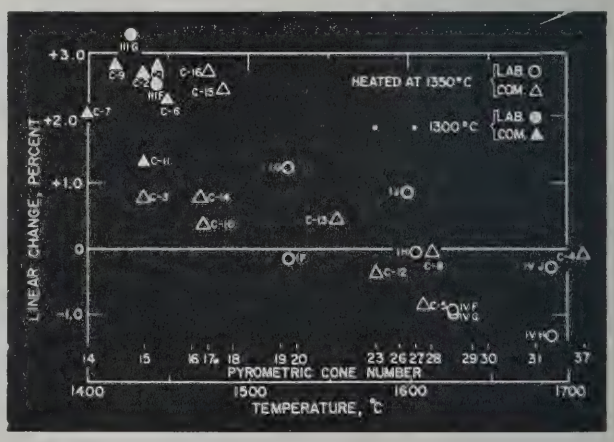
Enlarged single frame of a carbide bur cutting human enamel at a speed of 2,500 revolutions per minute (3,000 fps).

The photographic studies were combined with conventional laboratory test methods based on the weight loss of test materials when cut under controlled speeds and pressures. This combination provides a more complete approach to the study of design improvement of rotating dental cutting instruments.

For further technical details, see Cutting characteristics of dental burs as shown by high-speed microphotography, *by Jack L. Hartley, Donald C. Hudson, W. T. Sweeney, and W. P. Richardson, USAF School of Aviation Medicine Research Report (in press).*

Study of **Refractory Castables**

REFRACTORY castables are heat-resistant concretes consisting primarily of a refractory aggregate, such as crushed firebrick, bonded together with a high-alumina hydraulic cement. They are used in a variety of applications ranging from the combustion chambers of oil-burning home furnaces to the huge heat-treating furnaces in steel fabricating plants. Initial strength is developed because of the setting of the water-cement



Relation between pyrometric cone equivalent (an index of refractoriness) and linear change of refractory castables. The letters and numbers adjacent to plotted points refer to particular types of castables. For the laboratory-prepared castables, the symbols IV, I, III indicate 10, 20, and 30 percent cement, respectively. The scale of softening temperatures corresponding to the pyrometric cone equivalents is given for reference only.

mixture; but if the castable is used at high temperatures, its ultimate strength will be due to fusion of the cement into a ceramic bond.

To meet the need for comprehensive data on refractory castables, R. A. Heindl and Z. A. Post of the NBS have been conducting a long-range investigation of these materials for several years. Recently they completed a study which provides additional useful information on properties of castables and the effects produced by different types of heat treatments. Their results are based on laboratory-prepared mixes as well as on representative commercial castables and include data on both a domestic and an imported refractory cement.

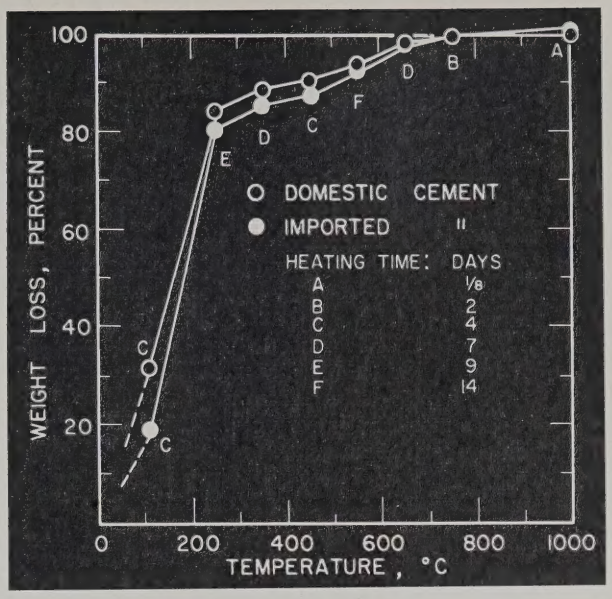
Two different aggregates, crushed calcined flint-clay and crushed fire-clay brick, were used in the laboratory-prepared castables, and each aggregate in turn was combined with each cement. The commercial castables totaled 16 which had been submitted by manufacturers for study. Properties such as flow of the wet mixes, particle-size distribution, and strengths in compression, tension, and flexure after curing, were investigated. After the specimens had been heated for periods up to 12 months at a number of temperatures ranging to 1,350° C, the resulting permanent linear changes were measured, and strengths in compression, tension, and flexure after curing were determined. Specimens were of three types: 2-inch cubes for compressive strength tests, 2×2×10-inch bars for modulus-of-rupture determinations, and figure-eight shapes for tensile tests. For most of the measurements on the laboratory-prepared castables, batches containing 10-, 20-, and 30-percent cement were utilized.

Although the pyrometric cone equivalent [1] of the commercial castables ranged from 14 to 37, most had a refractoriness below cone 18, which corresponds approximately to a softening temperature of 1,490° C. The loss in strength for both laboratory-prepared and commercial castables was more pronounced from room temperature through the heat treatment at 300° C than it was thereafter at various higher-temperature treatments through 1,050° C. The ceramic bond apparently began to develop for most of the castables with heat treatment at 1,125° C. In general, the strengths of the castables were higher after a 1-month heat treatment at 900° C than when heated for 5 hours at 900° C. However, for laboratory-prepared castables heated at 300° C, the compressive and transverse strengths after heating for 8 or 12 months were not significantly different from those obtained after a 4-month heat treatment.

Microscopic examination indicated no apparent changes in structure after the castables were heated to 1,050° C. However, after heating at 1,300° or 1,350° C, reaction rims around the particles of flint-clay aggregate were strongly in evidence. Also, the smaller particles of aggregate had turned completely brown in color during the course of reaction, probably because of absorption of iron oxide in the cement.

After heating 4 months at 300° C, the shrinkage of all compositions was small, in most cases about 0.1 percent. Additional heating at 300° C for a total of 8 months doubled or tripled the shrinkage, but the total remained small. For most specimens there was little increase in shrinkage between 8 and 12 months' heating. When the castables were heated at 1,300° or at 1,350° C for 5 hours, those with a pyrometric cone equivalent of 20 or below generally expanded while those with a PCE above 20 shrank.

[1] *An index of refractoriness, abbreviated PCE.*



Weight of water lost during the heating of hydrated high-alumina hydraulic cements.

At the end of 4 months at 300° C, the porosity of the castables containing the fire-clay brick aggregate (porosity 20.9 percent) averaged 30 percent, whereas those containing the flint-clay averaged from 27 to 28 percent. After heating at 300° C for a total of 6 months, the porosity was slightly lower for all but two of the compositions.

Specimens were also prepared from the two hydrated cements without aggregates and their weight losses after heat treatments at a series of increasing temperatures were determined. It was found that the hydrated cements lost about 80 percent of their free and combined water after heating 9 days at 250° C. The remaining water was more tenaceously held and was not removed until an additional 34 days had elapsed and the cements had been heated at 750° C. Thermal analysis curves of the hydrated cements showed endothermic deflections at about 110° and 280° C and an exothermic deflection at approximately 900° C. The two endothermic reactions may be attributed to the loss of water of hydration while the exothermic reaction may be due to the crystallization of amorphous alumina.

For further technical details, see Refractory castables: II, some properties and effect of heat-treatments, *by R. A. Heindl and Z. A. Post, J. Am. Ceramic Soc.* **37,** *5 (1954).* Preparation and properties of high-temperature concretes, *NBS Technical News Bulletin* **34,** *118 (August 1950),* Refractory castables, preparation and some properties, *by R. A. Heindl and Z. A. Post, J. Am. Ceramic Soc.* **33,** *7 (1950).*

ANNOUNCEMENT

Adoption of International Nautical Mile

BEGINNING on July 1, 1954, the National Bureau of Standards will use the International Nautical Mile in lieu of the U. S. Nautical Mile. This decision, replacing the U. S. Nautical Mile of 1,853.248 meters (6,080.20 feet) by the International Nautical Mile of 1,852 meters (6,076.10333 . . . feet), confirms an official agreement between the Secretary of Commerce and the Secretary of Defense to use the International Nautical Mile within their respective departments.

The use of a mile derived from the length of a degree of the earth's meridian is very old. It is believed that the Chaldean astronomers determined the length of such a unit. Miles of this sort have been variously called meridian miles, geographical miles, sea miles, and nautical miles, and they have differed greatly in magnitude, some of the values providing 10, 12, 15, and 60 miles to a degree. The British and the U. S. nautical miles were each derived by taking 60 nautical miles per degree, but the values adopted were not the same. The nautical mile adopted by the British Admiralty equals 6,080 British feet, while the U. S. nautical mile has had the adopted value of 1,853.248 meters, from which the equivalent 6,080.20 U. S. feet has been derived. The British foot is shorter than the U. S. foot by 1 part in 400,000, an amount which is of no importance in the ordinary transactions of everyday life but which is very important in precise measurements.

In 1929 the International Hydrographic Bureau obtained an agreement from a large number of countries to adopt a value of 1,852 meters for the nautical mile, the unit thus defined to be called the International Nautical Mile. However, at the same time Great Britain, the U. S. S. R., and the United States did not accept this value, each country preferring to retain the nautical mile to which it had been accustomed.

Finally, in 1953 an informal group from the Department of Defense and the Department of Commerce considered a proposal for international standardization of abbreviations for the knot and the mile. At this meeting the general situation regarding the nautical mile was discussed, and the belief was expressed that a change from 1,853.278 meters to 1,852 meters would not affect nautical charts, the calibration of navigational instruments, or navigation. Because there seemed to be no sound reason why the International Nautical Mile should not be adopted in this country, the Departments of Commerce and Defense agreed to accept this value as of July 1, 1954, the announcement to be made by the National Bureau of Standards.

Identical directives, in the names of the two departments, have been mutually adopted. The Department of Commerce directive is as follows:

Adoption of International Nautical Mile

I. Purpose

To adopt the International Nautical Mile for use as a standard value within the Department of Commerce.

II. Implementation

After the effective date of this directive, the International Nautical Mile (1,852 meters, 6,076.10333 feet), shall be used within the Department of Commerce as the standard length of the nautical mile.

III. Effective date

This directive is effective 1 July 1954.

Dedication of NBS Boulder Laboratories

THE BUREAU'S new research center in Boulder, Colorado will be officially dedicated September 11, 1954. Located on a 217-acre tract donated by the citizens of Boulder, the center includes both the NBS-AEC Cryogenic Engineering Laboratory and the NBS Central Radio Propagation Laboratory. Transfer of CRPL from Washington, D. C., to a recently finished multi-million-dollar building on the Boulder site is now complete. A scientific program planned in connection with the dedication will include a Conference on Cryogenic Engineering and a Symposium on Propagation, Standards, and Problems of the Ionosphere.

Conference on Cryogenic Engineering

The 1954 Conference on Cryogenic Engineering will be held September 8, 9, and 10 under sponsorship of the Bureau at the NBS-AEC Cryogenic Engineering Laboratory. The first meeting of its kind in this important new field, the Conference will treat engineering problems in the temperature range below 150° K (−123° C). Plans call for the presentation of technical papers which will deal chiefly with the production, storage, transportation, and use of low-temperature liquefied gases—hydrogen, nitrogen, and oxygen. Information regarding registration and reservations may be obtained from M. M. Reynolds of the NBS Boulder Laboratories, who is Chairman of the Conference.

Low-temperature liquefied gases are finding increased application in industry and national defense, making necessary larger, more convenient, and less hazardous equipment for producing and handling them. As a result, many new and highly complex engineering problems have arisen in the low-temperature field,

where much remains to be learned about the mechanical and thermal behavior of engineering materials and the nature of the processes. There are such marked differences between the behavior of matter at ordinary and very low temperatures that low-temperature properties cannot generally be obtained by extrapolation. Although low-temperature processes have been very useful in the past, further studies of the processes promise to be very fruitful. The NBS-AEC Cryogenic Engineering Laboratory has been engaged in this type of research and development since its inception in 1951.

Symposium on Radio Propagation and Standards

Symposium on Propagation, Standards, and Problems of the Ionosphere will be held September 8 to 11. Papers will include such topics as ionospheric radio propagation, tropospheric propagation, high-frequency standards, microwave standards, microwave techniques and applications, radio systems, radio spectrum utilization, atmospheric radio noise, radio astronomy, and upper atmosphere physics. Information regarding registration and reservations may be obtained from T. N. Gautier of the NBS Boulder Laboratories.

In addition to the technical sessions, field trips to the High Altitude Observatory at Climax, Colo., and the NBS Cheyenne Mountain Field Station at Colorado Springs have been arranged.

In general, the topics scheduled for discussion at the Symposium are closely related to the activities of the NBS Central Radio Propagation Laboratory. As the Nation's primary agency for research and coordination of data in radio propagation, CRPL analyzes and disseminates information on propagation conditions that aids global aviation, all-weather shipping and harbor control, and worldwide communications. The Laboratory is also responsible for the development and custody of the national primary standards for electrical quantities at radio frequencies.

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards, volume **53,** number 1, July 1954 (RP2510 to RP2516 incl.). Annual subscription $5.50.

Technical News Bulletin, volume **38,** number 7, July 1954. 10 cents. Annual subscription $1.00.

CRPL–119. Basic Radio Propagation Predictions for October 1954. Three months in advance. Issued July 1954. 10 cents. Annual subscription $1.00.

Research Papers

Reprints from Journal of Research, volume **53,** *number 1, July 1954. Single copies of Research Papers are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies, and request for the purchase price should be mailed promptly to that office.*

RP2510. Correlation of polarized light phenomena with the orientation of some metal crystals. C. J. Newton and H. C. Vacher.

RP2511. Separation of iodide, bromide, and chloride from one another and their subsequent determination. Thomas J. Murphy, W. Stanley Clabaugh, and Raleigh Gilchrist.

RP2512. Relative humidity-temperature relationships of some saturated salt solutions in the temperature range 0° to 50° C. Arnold Wexler and Saburo Hasegawa.

RP2513. Disintegration rate of carbon–14. R. S. Caswell, J. M. Brabant, and A. Schwebel.

RP2515. Bacher and Goudsmit theory of complex spectra. R. E. Trees.

RP2516. Self-ignition temperatures of combustible liquids. Nicholas P. Setchkin.

Circulars

C545. Subminature Techniques For Low-Frequency Receivers. Gustave Shapiro. 50 cents.

C539, Vol. III. Standard X-ray Diffraction Powder Patterns. H. Swanson, R. K. Fuyat, and G. M. Ugrinic. 45 cents.

Building Materials and Structures Reports

BMS140. Selected List of Building Construction and Maintenance. L. D. C. Nobel. 30 cents.

Miscellaneous

M210. Hydraulic Research in the United States. Helen K. Middleton (editor). $1.25.

Publications in Other Journals

The relation of occlusal surfaces to the stability of artificial dentures. Robert S. Ledley. J. Amer. Dental Assoc. (222 E. Superior St., Chicago 11, Illinois) **48,** 508 (May 1954).

Electron microscopy. Max Swerdlow. Anal. Chem. (1155 Sixteenth Street, NW., Washington 6, D. C.) **26,** 34 (January 1954).

On modified divided differences I. Gertrude Blanch. Mathematical Tables and Other Aids to Computation (2101 Constitution Avenue, NW., Washington, D. C.) **8,** No. 45, 1 (January 1954).

Pulse-height measurements of recoils from B^{10} (n, α) Li^7. James A. DeJuren and Hyman Rosenwasser. Phys. Rev. (57 East 55th Street, New York 22, N. Y.) **93,** No. 4, 831 (February 1954).

Laboratory standard microphones. R. K. Cook. Acustica (S. Hirzel, Clarindenhof, Gotthardstr. 6, Zurich, Switzerland) **4,** No. 1, 101 (1954).

Transmission of reverberant sound through walls. R. V. Waterhouse. Acustica (S. Hirzel, Clarindenhof, Gotthardstr. 6, Zurich, Switzerland) **4,** No. 1, 290 (1954).

An investigation of the effects of the nickel dip on the adherence of ground coat enamels to steel. D. G. Moore, J. W. Pitts, and W. N. Harrison. Finish (Dana Chase Publications, Chicago, Ill.) **11,** No. 5, 49 (May 1954).

A radioisotope study of the nickel dip. J. C. Richmond, H. B. Kirkpatrick and W. N. Harrison. Finish (Dana Chase Publications, Chicago, Ill.) **11,** No. 5, 49 (May 1954).

Some experiments in comparing the resistance of enamels to corrosion by alkaline solutions. H. B. Kirkpatrick, N. B. Balint, and J. C. Richmond. Finish (Dana Chase Publications, Chicago, Ill.) **11,** No. 5, 50 (May 1954).

Studies of oxidation behavior of enameling iron during firing. A. G. Eubanks, J. C. Richmond, and D. G. Moore. Finish (Dana Chase Publications, Chicago, Ill.) **11,** No. 5, 50 (May 1954).

Some factors affecting the adherence of ceramic coatings to alloys. J. W. Pitts and D. G. Moore. Finish (Dana Chase Publications, Chicago, Ill.) **11,** No. 5, 50 (May 1954).

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SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

August 1954 **Issued Monthly** **Vol. 38, No. 8**

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NBS Publications (continued)

Some problems in National and International standards. E. C. Crittenden. Sci. Monthly (1515 Massachusetts Avenue, NW., Washington 5, D. C.) **78,** No. 5, 278 (May 1954).

The elastic scattering of photons. E. G. Fuller and Evans Hayward. Phys. Rev. (57 East 55th Street, New York 22, N. Y.) **94,** No. 3, 732 (May 1954).

The vibrational spectra of *n*-dimethylaminodiborane. D. E. Mann. J. Chem. Phys. (57 East 55th Street, New York 22, N. Y.) **22,** 70 (1954).

The decomposition of CF4 in flames. D. E. Mann, H. P. Broida, and B. E. Squires. J. Chem. Phys. (57 East 55th Street, New York 22, N. Y.) **22,** 348 (1954).

The compressibility of liquid normal hydrogen from the boiling point to the central point at pressures up to 100 atmospheres. H. L. Johnston, Wm. E. Keller, and A. S. Friedman. J. Am. Chem. Soc. (1155 Sixteenth Street, NW., Washington 5, D. C.) **76,** 1482 (1954).

Pressure-volume-temperature relations of liquid normal deuterium. A. S. Friedman, Max Trzeciak, and H. L. Johnston. J. Am. Chem. Soc. (1155 Sixteenth Street, NW., Washington 5, D. C.) **76,** 1552 (1954).

The 4050 group of cometary spectra in the acetylene-oxygen flame. Norman H. Kiess and Arnold M. Bass. J. Chem. Phys. (57 East Fifty-fifth Street, New York 22, N. Y.) **22,** No. 3, 569 (March 1954).

Approximations in linear viscoelasticity theory: delta function approximations. Herbert Leaderman. J. Appl. Phys. (57 East Fifty-fifth Street, New York 22, N. Y.) **25,** No. 3, 294 (March 1954).

Rheology of polyisobutylene. Part I. Theory and experimental procedures. Herbert Leaderman. J. Polymer Sci. (250 Fifth Avenue, New York 1, N. Y.) **13,** No. 70, 371 (April 1954).

A stable voltage-controlled logarithmic attenuator. Gail E. Boggs. Proc. IRE (1 East Seventy-ninth Street, New York 21, New York) **42,** No. 4, 696 (April 1954).

Intensity distributions in nitrogen bands excited in auroras and by high-energy protons and hydrogen atoms. L. M. Branscomb, R. J. Shalek, and T. W. Bonner. Trans. Am. Geophys. Union (1530 P Street NW., Washington 5, D. C.) **35,** No. 1, 107 (February 1954).

The influence of heat treating variables on the martensite transformation in SAE 1050 steel. Melvin R. Meyerson and Samuel J. Rosenberg. Trans. Am. Soc. Metals (7301 Euclid Avenue, Cleveland 3, Ohio) **45,** 1225 (1954).

Some results of sweep-frequency investigation in the low frequency band. J. M. Watts and J. N. Brown. J. Geophys. Research (The Johns Hopkins Press, Baltimore 18, Maryland) **59,** No. 1, 71 (March 1954).

The Herzberg bands of O_2 in an oxygen afterglow and in the night-sky spectrum. H. P. Broida and A. G. Gaydon. Proc. Roy. Soc. (London) Series A. (Cambridge Univ. Press, Bentley House, 200 Euston Road, London NW1, England) **222,** 181 (1954).

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PATENTS

(The following U. S. Patents have been granted to NBS inventors.)

No. 2,680,830. June 8, 1954. Series-resonant high-voltage supply. Peter G. Sulzer. Assigned to the United States of America as represented by the Secretary of Commerce. See Electronics **25,** No. 9, 156 (September 1952).

No. 2,681,376. Alkaline primary battery and electrolyte therefor. Irving A. Denison and Paul L. Howard. Licensed to the United States of America as represented by the Secretary of the Navy. See Trans. Electrochem. Soc. **90,** 387 (1946); also J. Electrochem. Soc. **99,** 200C (1952); and NBS Tech. News Bull. No. 354, 76 (October 1946).

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